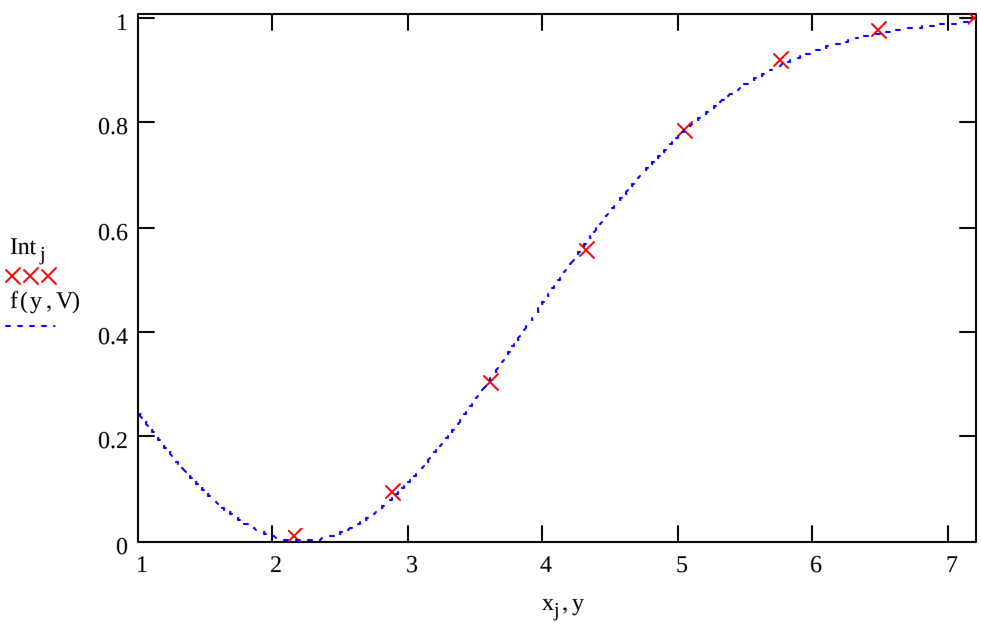
Study plan

1. Reference measurements
   - Measure beam current as function of scraper position
2. Measurements
   - Inject new beam
   - Scrape to 75% of initial current horizontally and then to 50% vertically
   - Remove scrapers
   - Wait 1 hour
   - Measure beam current as function of scraper position

Reference Measurement and its fitting



Dependence of beam current (T:IBEAM) on position of the vertical collimator (T:E01VCP); × - measurements, dotted line – fitting for gaussian an distribution

Theoretical description

For Coulomb scattering one can write an equation which simultaneously describe single and multiple scattering

$$\frac{\partial f}{\partial t} = \frac{D}{2L_c}\int_0^{\infty}\left[\frac{I' + I}{\left((I' - I)^2 + (I' + I)\Delta I\right)^{3/2}} - \frac{1}{\Delta I} d\left(I' - I\right)\right] f\left(I'\right) dI'$$

If one neglects single scattering this equation yields the standard diffusion equation for an oscillator

$$\frac{\partial f}{\partial t} = D\frac{\partial}{\partial I}\left(I\frac{\partial f}{\partial I}\right).$$

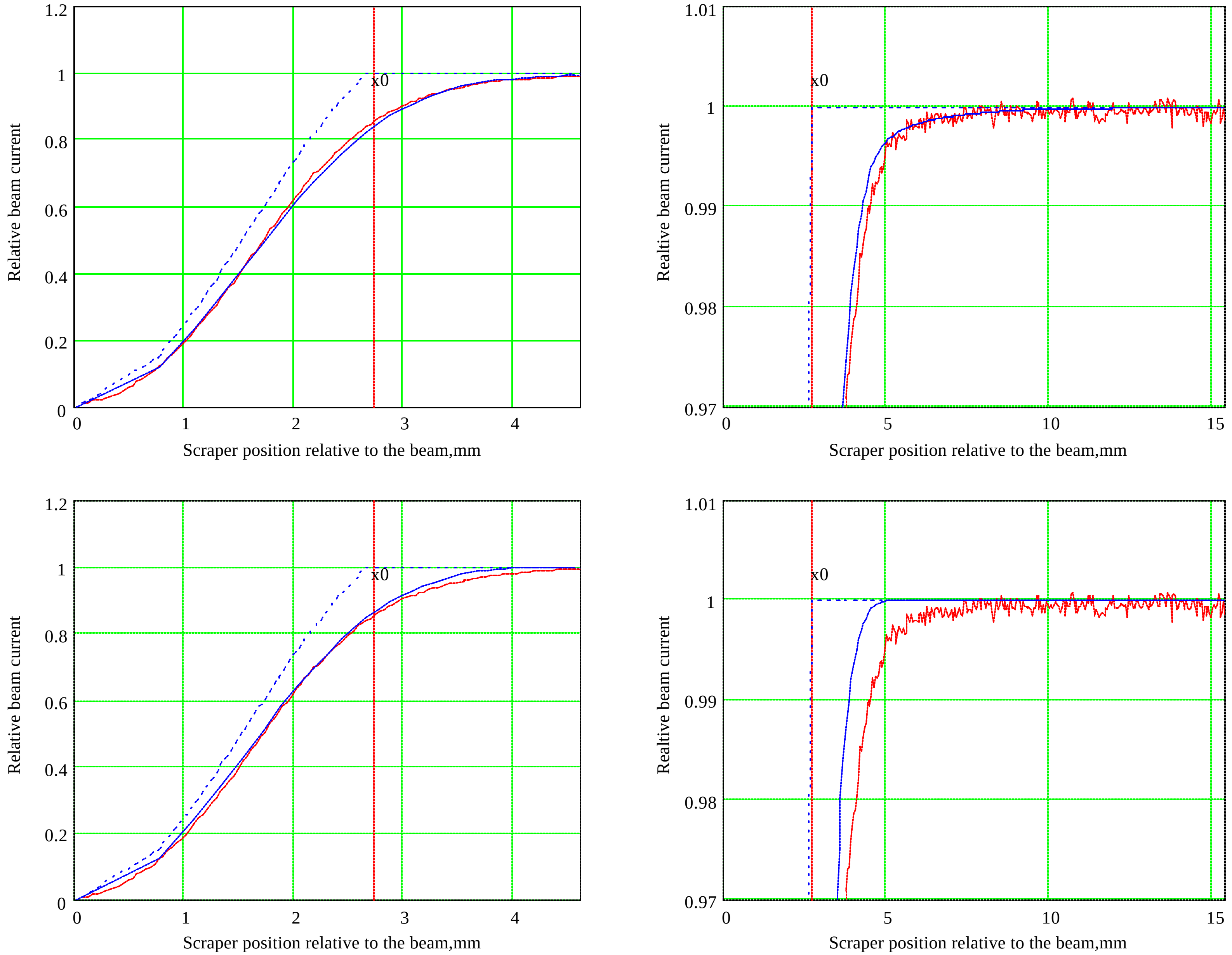
Here L_c is the Coulomb logarithm,

$I = \frac{x^2}{b}\left(1 + a^2\right) + 2axx' + bx'^2$ is the action,

$D = \frac{4pe^4 L_c}{P^2 \mathrm{v}_0}\sum_i Z_i^2 n_i \oint b(s)\frac{ds}{L}$ is the diffusion coefficient,

and $b(s)$ is the beta-function.

Measurement results



Dependence of the beam current on scraper positions after scraping the beam to 12 mm mrad and 1 hour beam expansion. Top - both multiple and single scattering are taken into account in the simulations; bottom – only multiple scattering is taken into account in the simulations. Blue line theory prediction, red –lines measurement results. Right side presents the same data but with better resolution of tails.

Conclusions

1.

Acceptance of the machine corresponding to initial scraper position	12 mm mrad
Measured emittance growth rate at 150 GeV	4.9 mm mrad / hour
Average vacuum expressed in the atomic hydrogen pressure	$4.1 \cdot 10^{-7}$ Torr

2. If we presume the same gas composition the average vacuum is approximately 20 times worse then in the Accumulator
3. Gas scattering is a major source of the beam heating. Coincidence between measured population in the tails and the model suggest that at least 80% of the transverse beam heating is related to multiple scattering on the residual gas. There may be larger contribution of the gas scattering but statistical accuracy of the data and not-sufficiently gaussian distribution of initial beam limit the coincidence between the theory and the measurements.

$$\mathrm{pmax} \cdot 10^9 = \begin{pmatrix} 14.42 \\ 18.54 \\ 0.618 \\ 0.309 \\ 0.258 \\ 0.515 \\ 0.309 \\ 0.412 \end{pmatrix} \qquad \begin{pmatrix} H \\ H_2 \\ CO \\ N_2 \\ C_2 H_2 \\ C \cdot H_4 \\ CO_2 \\ Ar \end{pmatrix}$$